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FOREST TREE DISEASES COMMON IN CALIFORNIA AND NEVADA.

A MANUAL FOR FIELD USE.

BY

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FOREST TREE DISEASES COMMON IN CALIFORNIA AND NEVADA.

SCOPE OF THE STUDY.

This manual, designed for practical use in the field, discusses only the more important tree diseases found in California and parts of Nevada, though most of them are common also in other forest regions. Its aim is to enable the field man to determine the cause of the commoner diseases and injuries and to understand their effect on the living tree. It discusses also ways and means of control of fungi and mistletoes, as well as climatic, biological, and soil conditions which bring about diseases in forest trees.

In studying forest tree diseases the object is of course to learn how to fight and control them. For success in this, however, we must at least know the more common forms of the enemies we are to deal with, how they act on the living tree, which organs they attack, how they do it, and what the consequences are. The simplest case of injury is destruction of certain parts of the tree, when, for instance, a few needles are browsed off by sheep or killed by needle miners or a fungus. In such cases the tree will hardly suffer, and there is no reason to speak of disease. If, however,

a great number of needles are destroyed the regular life functions of the tree are affected and it becomes diseased. With trees, as with animals, the various life functions are confined to certain organs, and anything which affects the health of these affects the functions as well. Disease is an unbalancing of normal functions, and to understand its nature we must first understand these functions and their relations to each other.

STRUCTURE OF THE TREE.

Trees grow in length in the youngest (end) part of the twigs and at the very ends of the roots; they grow in thickness in the so-called cambium, a very thin layer of cells between the bark and the wood of roots, stem, and branches. The cells of the twig ends, of the root tips, and of the cambium are capable of division, and certain young cells produced by this division, if properly nourished, grow to normal size, divide in turn, and so on. The growth in thickness (diameter) by the cambium takes place only in spring and early summer, and results in the production of a thin layer of wood all over the tree. In cross section this layer appears in the shape of the so-called annual ring, corresponding to one year's growth in diameter. The springwood of the annual ring is light and soft; the summerwood appears as a narrower, darker line and is harder than the other.

After a number of years the cells of the oldest annual rings of wood die and, after undergoing chemical changes, form what is called the heartwood. The living wood outside of the heartwood is called sapwood.

Only the inner portion of the bark, adjoining the sapwood and separated from it by the very thin cambium, is living; the outer portion consists of an impermeable skin or layer of cork or cork scales. The thicker these layers of cork scales the better protection they offer the living tissues from fungi and mistletoes, but not from insects.

NORMAL FUNCTIONS OF THE TREE.

All plants with green leaves or needles contain a green pigment which enables them to live on the very simplest food. They take up water and mineral salts through the roots and carbon dioxide and oxygen through the leaves; with help of the green pigment the plants produce under the influence of sunlight from these chemically simple materials the bulk of the chemically very complex substances of which they are built up. This function can be carried on only in sunlight. Animals and fungi, on the contrary, live on chemically very complex food, which they break up into simpler substances.

Large quantities of water containing comparatively little mineral salts are taken up by hairs on the very tips of the roots, which have to be continually renewed. Older roots take no part in this pumping of water from the ground. Their rôle is to anchor the plant in the soil. The roots, if not too old, also breathe to a certain extent; that is, they take oxygen from the air in the soil.

The water with the mineral salts is pumped through the roots and then through the trunk in the sapwood

upward to the leaves or needles. Enormous quantities of water are given off by the foliage in transpiration. The mineral salts accumulate and are utilized for various purposes.

The green leaves have three distinct functions—transpiration of water and its regulation, breathing (respiration), and assimilation of carbon dioxide.

Transpiration of water takes place through innumerable small openings in the leaves, which regulate to a certain degree the quantity of water thus given off.

Every plant breathes (respires) exactly as every animal does; that is, oxygen is taken up and carbon dioxide, the product of respiration, is discarded. This process goes on day and night, exactly as in the case of animals.

Carbon dioxide (a gas consisting of carbon and oxygen) from the atmosphere is assimilated by green leaves under the influence of sunlight. The carbon from the carbon dioxide, together with the water and mineral salts brought up from the roots, is used in the formation of chemical substances of highly complex nature (starch and sugar); the oxygen from the same source is exhaled. In the leaves also takes place the assimilation of nitrogenous salts and formation of albumen.

Starch, sugar, and albumens furnish food for the growing cells of the cambium and the root tips, being transported from the leaves, where they are formed, downward through the living bark. The surplus above the amount consumed is stored.

All these functions must be perfectly balanced. The development of the root system, for instance, which sup-

plies the water and mineral salts, is not independent of the development of the foliage. Both are correlated, and one must not overbalance the other.

DISEASE A DISTURBANCE OF NORMAL FUNCTIONS.

All diseases, properly speaking, can be traced to some interference with the normal functions just described and the economic equilibrium established in a sound tree.

Leaf diseases, by killing a greater part of the foliage, destroy the very organs in which food for the growing tissues of the tree is prepared. The cambium does not receive proper nourishment and can not grow, while the hairs on the root tips, which must be renewed continually, are no longer developed for lack of food, with the result that when once the surplus of food in storage in the wood is also exhausted no more water is pumped up to the remaining leaves.

Diseases of the bark of branches and trunk intercept the flow of food coming down in the bark from the leaves. The result is starvation of cambium and roots. This explains how damage is done by mistletoes, by *Peridermium* and other bark-destroying fungi, and by bark beetles. The effect is the same as girdling the tree with an ax. The bark also stores reserve materials, which are eliminated by the disease.

Diseases of the sapwood cut off the water supply which is pumped upward from the roots in the living sapwood to the upper parts of the tree, and the leaves suffer or die of drought. Any reserve materials stored in the sapwood are lost to the tree.

Diseases of the root system have the same disastrous effect on the water supply of the tree, and destroy the reserve materials stored in the roots.

Diseases of the flowers and seeds destroy the faculty of reproduction.

CAUSES OF DISEASE.

Whenever a tree, growing under the same conditions as its thrifty neighbors, appears in any way unhealthy, there is reason to assume some kind of attack by parasitic fungi, mistletoes, or insects. Yet there are quite a number of other things which bring about disease or death in trees, and before we decide finally that one of the three factors named is responsible, except of course where there can be no possible doubt, we should first make sure that there is not some other cause for the abnormal condition of the tree in question. Parasites are plants or animals which live off the living tissues of other plants or animals, not merely by mechanically destroying them, but by partly or totally penetrating the tissues of the so-called "host"—that is, the plant or animal they live on. Certain parasites are able to enter the youngest parts of trees, twigs, or leaves directly; the majority of fungi causing decay of the wood can get into the interior of the living tree only by way of a pin knot or a wound. For this reason every wound caused by lightning, by fire, by man, or by animals constitutes a menace of infection, unless it receives an aseptic dressing such as the coniferous trees to a certain extent give in covering the exposed surface with resin.

Smaller wounds in pines are, as a rule, soon covered over by pitch, which very effectively prevents the drying out of the exposed sapwood and the germination and growth of fungus spores. The less resinous conifers and our broadleaf trees lack this protection, and even the pines are unable to cover very large wounds completely. The sapwood dies, dries out, and checks. Spores (p. 28) of parasitic fungi enter the cracks, germinate, and infect the heartwood. Proper moisture and temperature are the necessary conditions for germination of the spores; but infection can only take place if the spores land where the mycelium resulting from germination finds the proper food for further development. The spore of a heartwood-inhabiting fungus, such as *Polyporus amarus*, for instance, must be carried on to an incense cedar, since the fungus can not attack any other tree. If it lands on the bark it may germinate, but the resulting mycelium is unable to penetrate into the heartwood. Only when a spore is deposited on a broken-off branch stub, which allows the mycelium to grow through it into the heartwood of the bole, or when a spore falls onto an open wound large and deep enough to offer an entrance into the heartwood either directly or through cracks, can infection take place. Thus certain diseases of the heartwood (rot or decay) can very frequently be traced directly to fire scars, lightning scars, spike tops, stubs of broken limbs and branches, and even to the crotches of forked trees, where the swaying of the two forks in the wind mechanically destroys the tissues. Moisture nat-

urally gathers here, and spores find the most favorable conditions for germination.

Resin is not the only means of natural protection. All trees have the faculty, though in varying degrees, of healing over wounds and growing over pin knots and stubs. This is, of course, a very slow process, and the tree is subject to infection until it is completed.

Purely mechanical destruction is not disease, but it may produce disease. Porcupines, for instance, will live off the tender bark of young pines (Jeffrey pine, lodgepole pine) when the snow is too deep for them to get any other food. As long as they destroy only small patches of living bark no material damage is done. Insignificant injury caused by mechanical destruction of small parts of vital organs is soon overcome in a healthy tree; the remaining sound tissues simply take over the surplus work to be done—they work "overtime." But when not enough bark remains to perform the functions required of it, all parts of the tree above the point of attack soon show signs of suffering. The same holds true for insects. A tree scarcely suffers from the attack of isolated insects; but when they appear in great numbers and practically girdle the trunk the tree is seriously injured.

Mechanical destruction is brought about by man, by animals, by lightning, fire and storm, cloudbursts, heavy snowfall, etc. Carelessness in felling timber, removal of bark for roofing of cabins, unnecessary and extravagant blazing, tapping of Jeffrey pine for resin and abietene are only a few examples of the destructive ac-

tivity of man in the forest. Insects destroy the foliage, fruit, bark, or wood. Porcupines, deer, cattle, sheep, and other mammals partly live off the green bark, partly browse off the foliage. Rodents sometimes injure the roots, particularly of very young trees.

Lightning will not in every case kill the tree it strikes. As a rule, however, its effect is only realized when a heavy discharge strikes a tree and injures it very severely. But when, as in most cases, the electricity discharged over a forest is divided into a number of weaker currents, which strike as many dominant trees, each of which acts as a conductor, the effect on the single tree becomes less apparent and is easily overlooked. Lightning is very often the cause of spike tops (in case of white firs see also p. 57). Grooves and streaks on the bark and smaller wounds caused by lightning are very common.

The effects of fire are too well known to need description. It should be remembered, however, that often a tree may appear green and healthy for as long as two or three years after a fire, only to succumb at last to the injuries received. Decay in very many cases is directly traceable to old fire scars; in fact, fire as a cause of wounds is responsible for more cases of heart-rot than all other factors taken together. The charred surface of exposed wood in the beginning affords protection to the wood underneath it, but soon the charcoal is partly worn off, and the sapwood, which is no longer protected by the bark, dies and checks, thus offering an easy entrance to the germinating spores of wood-destroying fungi.

Heavy storms may injure a tree in various ways. Tops or limbs or the trunk are broken off. Sometimes part of the roots of a tree which is poorly anchored in the soil may be torn off and the tree completely uprooted and blown over. In falling such trees frequently injure their neighbors.

When a cloudburst displaces the ordinary bed of a mountain stream, any trees caught in the torrent, even if they withstand the pressure of the water, suffer more or less from the action of rolling bowlders, which rub off the bark, and later from the changes brought about in their life conditions by the thick layer of débris left after the stream has receded.

Other causes of disease are smelter fumes and smoke, frost, sunscald, drought, and excess of water in the soil. In the neighborhood of smelters and other large industrial plants which burn great quantities of coal the forests, particularly in the direction of the prevailing winds, are often very seriously injured by the poisonous gases escaping either from the ore or from the coal used.

Winter frost sometimes causes long internal cracks in older forest trees, often corresponding to rather conspicuous perpendicular ridges on the outside of the trunk. Late frosts are likely to kill young shoots (see, however, white fir, p. 37). In long, dry winters the foliage of coniferous trees is often stimulated on warmer days to transpiration of water, which the root system is not able to restore from the frost-bound soil. The needles then die and turn red.

Sunscald is common on thin-barked trees, particularly after sudden exposure to strong sunlight by thinning, snowbreak, etc.

Heavy snowfall often causes serious damage by bending and breaking young trees or branches, or by favoring the development of certain fungi (*Herpotrichia nigra*).

EXAMINATION OF DISEASED TREES.

The nature of a disease can be determined only by keeping in mind all the possible factors which make for disease (see "Causes of disease," p. 12), and the way they affect the functions of the normal tree (see "Disease a disturbance of normal functions," p. 11). By taking into consideration all possibilities and by discarding everything that does not suit the particular case we finally arrive at a comparatively small group from which by careful examination we will as a rule be able to choose the correct answer to our problem. It should be remembered, however, that a disease is not always encountered under its most typical aspect. A tree attacked by a fungus may show signs of suffering, but the fungus itself may not yet be sufficiently developed to form fruiting bodies (p. 25). In other cases the fruiting bodies may be very small, very inconspicuous, or hidden on the roots or under the bark. The fruiting bodies of certain fungi even vary considerably with host and climate (Pls. IV and V). Examination of diseased trees, therefore, can not be too careful.

No age is free from disease; but certain diseases are confined to definite ages. Some fungi, for instance, only attack young reproduction or branches and twigs in the same youthful stage of development. Others are confined to mature and overmature trees.

Few implements are required for the examination of diseased trees. A hatchet or an ax is sufficient for opening up the bark or outer layers of wood. A pick and shovel are needed when the seat of the disease seems to be in the root system. Whenever parts of the trunk, branches, or the root system are affected or killed, it is important to find out the extent of the disease and, if possible, to follow any abnormal signs to their source. For the examination of the foliage an ordinary magnifying glass will do in most cases.

SYMPTOMS OF DISEASE.

The foliage being the most sensitive visible organ, its general aspect is a valuable index of the health of a tree. When the foliage of a coniferous tree, for example, appears to be diseased, and no other cause, such as drought, girdling, smelter fumes, or recent fire, can be found, the needles should be held to the light to see whether they are hollowed out by needle miners, the larvæ or pupæ of which may at certain times be found inside them. Partial or total destruction of the needles or leaves is due to browsing by mammals or to caterpillars and the larvæ of sawflies. We may also find the fruiting stage of a fungus in the shape of small black spots or narrow black lines on discolored parts of the

leaf or needle. Often the fruiting bodies develop only on the underside of the needles or leaves.

Premature dying of the foliage of tops, limbs, branches, or twigs may be an indication of local interference with the water supply, the result of partial or complete girdling by porcupines and other mammals (deer, cattle, sheep) or by insects. Leaf or twig inhabiting fungi may, however, locally attack the foliage. Lightning sometimes kills limbs. On old yellow pines, for instance, it is often possible to follow the track a discharge of lightning has taken down the tree by the limbs it has killed on its way. Dead limbs may also be an outward sign of some local trouble in the root system.

Partial or total dying (reddening, yellowing, premature dropping) of the foliage of single trees may be caused by a variety of agencies, but can, except in the case of needle miners and certain needle fungi, almost invariably be traced to some interference with the water supply. If the tree dies in a comparatively short time, the probabilities are that the trouble is located at the butt or in the root system. It is frequently, but not always, a sign of attack by bark beetles.

When the foliage of practically all the trees in a stand is affected at the same time it indicates that the leaves or needles may have been poisoned by smelter fumes or similar gaseous products or killed by fire. It may also mean invasion by insects or that the water supply is in some way out of order (winter injury, p. 16).

Disturbances of the root functions caused by drought or by an excess of water in the soil, total or partial destruction of the roots by parasitic fungi, insects, rodents, etc., or starvation of the root tips caused by diseases or destruction of the living bark above by fungi, insects, porcupines, etc., all tend to cut off the water supply of the tree, the results of which are felt first in the needles or leaves. Certain winter conditions have the same effect (see p. 16). Resin flow at the butt of the tree frequently indicates root disease.

When twigs appear to be diseased examination should be made of the part of the twig where the sound and diseased tissues meet. In the case of fungus attack small black spots will often appear on the diseased or dead twig. Sometimes twigs are killed by rodents eating the bark or by deer brushing it off from the underside. If insects have attacked twigs, their presence is indicated by borings in the bark or wood. All this applies, of course, not only to twigs, but also to leaders; in fact, to all the younger shoots of mature and immature trees. The youngest twig endings of firs may be killed in spring by frost, by a parasitic fungus, or by insects. Galls on the twigs or branches are caused by insects or by a fungus (*Peridermium*).

Dead branches and limbs in the otherwise healthy crown are always suspicious. The various causes of death have been mentioned under "Premature dying of the foliage, tops, limbs, branches, or twigs."

Any alteration of the normal branching system of a tree suggests the presence of some injurious agent. The mycelium of certain fungi spreads into the twigs

and even into the branches, causing the formation of "witches' brooms." These are alterations in the normal system of branching peculiar to every species of tree, and are due to the stimulation caused by the parasite growing in the tissues of the branches or twigs. Witches' brooms are very common on wild cherries and plums, where they are caused by a fungus. Some witches' brooms (on conifers) are produced by mistletoes (p. 56). Occasionally, however, their formation is due to excess of nourishment. This is the case with the rather rare witches' brooms on yellow pine, caused by *Peridermium* knots, which "girdle" the branch and stop the downward flow of the food prepared in the needles above (p. 39). Other witches' brooms are caused by mites or insects.

Toadstools or conchs (see p. 28 and Pl. V and others) on trunks and limbs indicate the presence of parasitic fungi and rot in the wood. Until they develop, no outward sign of disease may be visible. Diseases of the trunk or limbs may affect either the sapwood or the heartwood, or both. Disease of the sapwood of coniferous trees is often indicated by a heavy flow of resin from the bark. Resin flow on the butt of the tree points to disease of the root collar and the roots. In cases of this kind we will often find white mycelium (see p. 25) under the bark or between the bark scales of the butt (see pp. 42 and 53). On the trunk, where it is not clearly explained by a wound, it is always more or less suspicious.

It is well to be on the lookout for any abnormal appearance of the trunk. Cat faces, burls, thick protruding knots, deep knot holes, and abnormal resin flow

are always suspicious, and while the decay which they very commonly indicate may not in all cases extend very far, it must not be left out of consideration. Decay very frequently extends down the trunk from dead limbs and dead tops. How far the decay extends through the trunk depends very much upon the species of tree and the species of fungus inhabiting it. The resinous pines suffer least; in spike-topped Douglas firs, white firs, and red firs usually one or more upper logs are decayed. In judging a tree every slight swelling and depression on the trunk has to be considered, as well as the appearance, color, and quality of the bark. This involves, of course, a thorough knowledge of normal conditions.

Heartrot is not a disease in the proper sense of the word; the heartwood is dead and thus can not be said to be diseased. Heartrots, however, are extremely important from an economic point of view, and are therefore usually treated as timber diseases. It is often very difficult to diagnose typical heartrot from the outside. In very many cases the tree outwardly appears to be perfectly healthy, while the heartwood is almost completely destroyed. In seemingly sound white fir logs it is often possible to diagnose decay from the Indian paint fungus by the presence of branch stubs which show the characteristic rusty-red color produced by this fungus ("rusty knots"; see p. 51).

In our semiarid mountains, many stools (conchs or fruiting bodies, p. 25) of the fungi which cause heartrot are produced during fall, winter, or spring, and with exception of the harder, more woodlike forms,

are soon destroyed by insect larvæ or by squirrels. Careful observation will frequently detect at least some remains of these stools. On incense cedar, for instance, the soft and juicy fruiting bodies are readily destroyed by the larvæ of certain insects, many of which then bore into the dead outer bark of the tree. These are eagerly sought after by woodpeckers, which chop them out of the bark. The space formerly occupied by the fruiting body then appears as a cup-shaped depression, which seems to be pierced by innumerable fine shot holes, the burrows of the insect larvæ. Insect work on pines is indicated by pitch tubes on the bark, which are characteristic of the attack of *Dendroctonus* beetles. In such cases the bark should be peeled off here and there to verify the presence of insect work.

Longitudinal rows of small holes in the wood are caused either by woodpeckers or by the roots of mistletoes. The latter kind are particularly conspicuous in the sapwood under the bark. Woodpeckers very frequently bore horizontal rows of holes in the bark, which often heal over, leaving, as an outward sign, peculiar protruding ridges.

The weakening of a tree by one injurious agent very often opens the road to another, which would not have been able to attack the sound tree. Cankers on the trunks of white fir, caused by *Razoumofskya*, are very commonly connected with stringy brown rot, caused by *Echinodontium tinctorum* (p. 50). Certain insects almost invariably follow injury by fire. Insects and parasitic fungi or mistletoe very often work in this way for each other and in collaboration.

All the injurious agencies mentioned can combine. The same tree might suffer at the same time from needle miners, needle disease, mistletoes, root diseases, bark beetles, drought, etc. Different diseases will also attack the same tree at different stages of its life.

FUNGI.

NATURE AND DEVELOPMENT.

Most of the diseases of our forest trees are due to fungi. A fungus is a very simple plant without green pigment, and as such is unable to assimilate carbon dioxide. It is unable to live on simple food and to build up more complex chemical matter. A fungus lives on highly composite matter produced by green plants and decomposes it into simple matter, which again becomes available for green plants. The fungi share this function with the bacteria and animals, and therefore play a very important part in nature's economy. A great number of fungi live in the soil on dead, decomposing vegetable and animal matter; others attack living plants, and in so far as they injure or destroy these by living on and in their tissues are called parasites.

Not all wood-destroying fungi can live indiscriminately in all trees; some are confined to one species, others have a predilection for certain groups of trees. They are just as dependent upon certain definite kinds of food as are other plants and animals. Few attack any trees within their reach. Different fungi not only have a distinct predilection for certain species of trees,

but also for certain parts of the tree. A leaf or needle fungus, for example, will never attack the heartwood or the roots of a tree.

The fungous plant proper consists of extremely delicate threads (hyphæ), mostly invisible to the naked eye, unless they appear in masses, for instance, in shape of white felts in decayed wood. The hyphæ of a fungus are called, collectively, mycelium (Pl. VIII). The hyphæ of the parasitic fungi we are mostly concerned with live inside the tree, in the tissues of the trunk, roots, or leaves. They grow and produce fruiting bodies (sporophores). As the name indicates, these are not the fungus itself, but what may be termed its "fruit," producing "spores." The conch or stool on the trunk of a Douglas fir, for example, is not the fungous plant; this lives in the interior of the tree, and the conch is nothing but the fruiting body.

The fruiting bodies are only formed after the fungus plant (mycelium) in the host tree has reached a certain maturity at the cost of the tissues (cells or cell contents) they live in. The fruiting bodies of some fungi are formed annually; others are perennial. The mycelium of a fungus may be likened to the root system of the higher plants, which pervades a given volume of soil according to the species and the state of development of the plant. In the same way in which the root system of a mature grass plant, for instance, takes its raw food and water from an infinitely smaller volume of soil than that of a mature yellow pine, the mycelium of a needle-inhabiting fungus occupies a very much smaller volume of host tissue than that of

a wood-destroying fungus in a large tree. At the earliest stage of development the mycelium of a wood-destroying fungus, starting, for instance, from a large burn in the butt of the tree, lives on a few wood cells; in other words, the volume of decayed wood is still very small; in growing the mycelium permeates a larger volume of wood, and when it is sufficiently mature to produce fruiting bodies it must have drawn its substance from a considerable volume of wood, which, in doing so, it has reduced to what we call decay. The first appearance of a fruiting body on the bole of the affected tree, therefore, gives us an indication of a certain development of mycelium in the heartwood and, consequently, of the extent of decay. Annual fruiting bodies grow very fast, and are either destroyed during summer by insect larvæ and squirrels or they die off in fall and rot. The mycelium in the tree, however, continues to grow by attacking hitherto sound wood, and in the next year a new fruiting body indicates the progress of the mycelium in the wood and, consequently, of the decay. Perennial fruiting bodies grow in size from year to year; therefore, their dimensions will constitute an equally valuable indication as to the corresponding extent of the mycelium and the decay in the heartwood. Practical knowledge of this relation becomes particularly valuable in reconnaissance and in estimating standing timber.

The extent of decay varies, of course, very much, not only with the species of fungus and the species of tree, but also with the development of heartwood and its chemical and physical qualities. Evidently there

can be no heartrot in trees too young to form heartwood; but even after the differentiation of the wood into heartwood and sapwood has begun, the heartwood is for a time more or less immune from attack. After a number of years, however, the heartwood has changed so much in character that it becomes proper food for heartwood-destroying fungi. The relative extent of decay by *Echinodontium tinctorum* is far greater in slow-growing, suppressed white firs than in thrifty ones, in part, perhaps, because the heartwood of thrifty-growing trees differs in character from that of suppressed trees.

The decay is due to the action of the fungus hyphæ on the cell-walls of the wood. They use certain components of the cell-walls for food and leave the rest, so that the structure of the cell-walls is broken down. Wood recently invaded by the hyphæ does not yet show actual decay; although it is already under the influence of the " advance guard " of the fungus, it appears sound or only slightly changed in color or consistency. It is only after prolonged action of the mycelium that the wood structure actually breaks down. Thus, the wood separating the dry-rot pockets in incense cedar caused by *Polyporus amarus* (p. 46) looks perfectly sound, although it must, of course, contain hyphæ which connect the mycelium of one pocket with another; it has lost nothing of its strength, while the wood in the pockets is completely destroyed. In the development of the mycelium of the Indian paint fungus in white fir the hyphæ advance steadily, not in leaps, as that of *Polyporus amarus* in incense cedar. The part of the

wood covered by these pioneer hyphæ, although somewhat discolored and spongy, often appears sound enough to be given full scale. In reality, it has lost a good deal of its strength and generally falls to pieces in drying after having gone through the mill. Timber with this "advance rot" should be classed as cull. The classification of white fir by lumbermen as an "inferior species" is very largely due to financial losses arising from handling logs with advance rot.

The presence of a fruiting body on a dead or dying tree does not necessarily constitute a cause of alarm, as many fungi are not only harmless, but absolutely necessary for the economic equilibrium of nature. The presence, however, of any fungus in leaves, needles, or fruits (cones) or of any fruiting body on a living tree is at least suspicious.

Young fruiting bodies naturally differ very much in aspect from older or dry specimens or ones that may be abnormally developed; in comparing a fungus found in the field with descriptions or photographs given in this manual, these two points must not be overlooked.

In nature we find an enormous variety of fruiting bodies. These may appear on needles and twigs in the form of small, round black spots or black lines and on tree trunks, logs, or branches as stools (shelves, conchs, toadstools), or crusts. In different ways they all produce spores ("seed") in enormous quantities.

The spores are invisible to the naked eye, are very light, and are carried about by air currents and sometimes by insects to other trees. Wherever they find favorable conditions they germinate and start their

destructive activity. Thus a single spore of diminutive size may be the cause of complete destruction of a large mature tree.

The spores of fruiting bodies which appear in the form of shelves, conchs, or toadstools are usually developed on the underside. This underside or lower surface is nearly always more or less horizontal, which often makes it possible to determine whether a fruiting body was formed on the living tree or after the tree had fallen. In this group of fungi the underside of the fruiting body is either porous (Pl. IV), spiny (Pl. XVII), or gill-bearing (Pl. III).

FUNGI WITH FRUITING BODIES IN THE FORM OF STOOLS OR CRUSTS.

POROUS FUNGI.

In porous fungi the underside is pierced by innumerable holes (pores) which are the openings of tubes. These tubes are nearly always perpendicular, and the spores are developed on the lining of the walls. The pores are sometimes elongated, forming an irregular network. Fungi of this group are often injurious to cut timber, such as railroad ties (Pl. II). The fruiting bodies of the porous fungi are described as shelf, bracket, or hoof-shaped, or as crusts, according to their form.

SPINY FUNGI.

The underside of fruiting bodies of this kind of fungus is made up of spines or teeth, on the surface of

which the spores are developed. Examples are the fungus causing the stringy brown rot of white fir (*Echinodontium tinctorum*, Pl. XVII), which is perhaps the greatest enemy of this species; and the fungus *Hydnum erinaceus*, which causes a destructive rot of the heartwood of oak. While the spiny fungi are not found on many species of trees, they are very injurious.

GILL-BEARING FUNGI.

This group takes its name from the regular blade-like gills on the underside of the fruiting bodies, radiating from the stalk (mushrooms). The spores are developed on the sides of the gills.

FUNGI WITH FRUITING BODIES NOT IN THE FORM OF STOOLS OR CRUSTS.

LEAF AND TWIG FUNGI.

The fruiting bodies of leaf and twig fungi present a great variety of forms, often, however, they appear as black spots or lines. They, too, produce spores, which carry the disease to sound organs.

ATTACK ON VITAL AND NONVITAL PARTS OF THE TREE.

The fungi which attack forest trees may be divided roughly into two groups—those which cause disease or death of vital parts of a tree and those which destroy nonvital parts.

FUNGI WHICH ATTACK VITAL PARTS OF THE TREE.

An example of the first group are the needle fungi. Partial destruction of the foliage is not always fatal

to a tree, but in consequence of the starvation of the cambium there is little or no annual growth. Other fungi will destroy the roots and the living bark and cambium of the butt, and often the tree will die, but in the case of trees with a rich flow of resin, such as pines, the resin will not allow the fungus to develop in the wood of the trunk, which remains sound until it is attacked and destroyed by other nonparasitic fungi. The timber in such trees can be saved, if disposed of in time. Firs, on the other hand, are less effectively protected by resin, and the mycelium, entering the trunk, causes decay of the dead heartwood. Twig-inhabiting fungi often cause distortions.

FUNGI WHICH ATTACK NONVITAL PARTS OF THE TREE.

This group includes the economically very important wood-destroying fungi. They can not strictly be called parasites, since they live in the dead heartwood. They rarely endanger the life of the tree. Completely hollow white firs and Douglas firs often appear thrifty. However, these fungi often bring about indirectly the death of the tree by weakening it mechanically to such an extent that it is blown over or broken off in a heavy storm.

The destruction of valuable timber by these fungi means very heavy financial losses, not only in merchantable timber, but in the ensuing depreciation in value of the affected species. Incense cedar, instead of ranking as an "inferior" species, would be one of the most valuable forest trees of the Sierra Nevada were it not for the fact that often as much as 75 or even

100 per cent of mature incense cedar is affected with dry rot. The same is true, although not always to the same extent, of white fir and red fir.

The fungi of this group are all more or less closely related to one another. Their fruiting bodies are usually large and conspicuous, and appear in the shape of conchs, shelves, toadstools, or crusts (see p. 29). Some develop fruiting bodies on the living tree, others after the death of their victim, or on both the living and the dead tree.

DISEASES OF FOLIAGE, TWIGS, AND BRANCHES.

EFFECT.

Needle and leaf, twig and branch diseases affect the prospective value of growing trees—that is, the future crop—since they interfere with the production of merchantable timber; wood-destroying fungi, on the other hand, endanger our present capital of timber. The diseases of the foliage, twigs, and branches are more dangerous to immature than to mature trees. If only a few leaves and branches are killed, others replace them, or their functions are taken over by those that remain. When, however, the damage is considerable, the remaining organs are not able to assume the whole work, and the equilibrium between foliage and root system is seriously disturbed. Growth is retarded, and the tree may eventually die. If this should happen before the tree is ready for the ax, the loss in expected timber is complete. Should an old tree die from the attack of these fungi, on the other hand, the damage

done, from a commercial viewpoint, consists only in the cessation of annual growth. The timber already formed remains available, unless destroyed by secondary, nonparasitic fungi.

NEEDLE DISEASE OF WHITE AND RED FIR.

A disease of young white and red fir kills all needles except the youngest on the ends of the twigs, causing them to turn reddish gray, and finally to drop off. The green needles which remain on the ends of the twigs give the almost naked tree a green outline. The lower parts of the tree suffer most. In severe cases the disease results in almost complete defoliation. The fruiting bodies of the fungus *Lophodermium nervisequium* appear in long black streaks following the middle line on the underside of the needles.

TAR-SPOT FUNGUS.

The fungus *Rhytisma* is occasionally found on the leaves of Oregon maple (broadleaf maple). It takes its name from the black, tar-like dots which are evenly distributed over round, yellowish, slightly raised spots of about the size of a nickel. The black dots contain the very small fruiting bodies. If in great numbers, these spots seriously interfere with the functions of the leaves.

NEEDLE FUNGUS OF LODGEPOLE PINE.

The foliage of lodgepole pine, especially in stands about the higher meadows of the Sierra Nevada, often

appears exceedingly thin. Most of the needles have dropped off, and the few that remain are either dying or dead. The only green needles stand in a meager tuft at the end of the twig. The damage is due to the attack of a needle fungus (a species of *Hypoderma*), the leaves showing broad, transverse zones of light gray or yellowish brown, sometimes alternating with zones of green. The fruiting bodies appear on both sides of the middle nerve in the shape of short, narrow, black lines. The disease seems to be quite serious in some localities and is likely to do great damage where it results in almost complete defoliation of the tree.

NEEDLE DISEASE OF YELLOW PINE.

The needles of yellow pine, which normally remain on the twigs from 3 to 7 years, are often killed down to the last one or two years by a fungus (probably a species of *Lophodermium*), and either drop off, with the result that the foliage appears very thin, or else remain hanging on the branches for many years, giving the tree a "whiskered" appearance. From green they turn to yellow and later to silvery gray. The increment of the tree is very seriously affected by this disease, which does considerable damage. The fruiting bodies of the fungus appear in the shape of very small, black, irregular spots or short lines.

STUNTING NEEDLE FUNGUS OF YELLOW AND JEFFREY PINES.

A very destructive needle fungus (*Hypoderma*) attacks both yellow and Jeffrey pine, often killing all

needles except the very youngest and weakening even these. The needles are mostly short and stunted, or characteristically curled. The fruiting bodies appear in thin, black lines from one-eighth to one-half inch in length. Sometimes the disease appears to attack only certain branches; in other cases the entire tree is affected. It may also enter the twigs and cripple them, causing the formation of "witches' brooms."

YELLOW WITCHES' BROOMS OF WHITE AND RED FIR.

A bright yellow witches' broom of peculiar shape appears on the branches of older red and white fir, due to a fungus (*Peridermium elatinum*), which develops its fruiting bodies on the deformed needles. The yellow witches' brooms are very conspicuous, standing out strongly against the dark green of the sound foliage.

INCENSE CEDAR RUST.

This disease is confined to incense cedar of all ages. The same fungus (*Gymnosporangium blasdaleanum*) causes two distinct forms of it, both of which may appear, together with intermediate forms, on the same tree.

In early spring many of the small sprays of incense cedar trees, from sapling to pole size, especially those growing in damp gulches, appear slightly discolored. On the under side, or more rarely the upper side, of the green, flat, scale-like leaves a number of small, hairy, brown to brick-colored tufts or cushions appear. When mature, these cushions become gelatinous during the

spring rains and finally unite with neighboring cushions to form rather conspicuous, slimy, and light orange-colored masses, which later dry up to a thin film and finally drop off. By this time the sprays have turned quite yellow. Later they die.

This form of the disease must not be confounded with the work of a beetle which girdles the twigs, causing them suddenly to turn yellowish-white and hang down as though broken. Sprays killed by a rust never have this appearance and are yellower than those killed by the beetle. The small cushions on the underside of the leaves are composed of the winter spores of the fungus. These germinate during the warm spring rains, and produce a second kind of very small spores. The fungus leaves the incense cedar for the time being and chooses another host (western service-berry), upon the young leaves of which the secondary spores germinate. After a short time very small, orange-colored, cup-shaped fruiting bodies appear on the leaves, and the spores produced in these are then again able to infect incense cedar.

Incense cedar witches' brooms, which are very common, are also caused by the rust fungus. Only the smaller sprays, apparently, are killed by the mycelium. If these alone are attacked, no deformation of the host tree is noticeable. When the mycelium enters an older twig, however, it locally changes the branching system. The resulting witches' brooms (p. 21) are numerous and conspicuous. The cushions of winter spores develop on small sprays at the base of these, and

the sprays usually turn yellow and die. Badly infected trees may be seriously injured. Witches' brooms are found even on small saplings.

At a distance the witches' brooms might be taken for plants of the incense cedar mistletoe (p. 57). The latter, however, always hangs down in thick clusters, while the bushy witches' brooms stand more or less erect.

BLUE WITCHES' BROOMS OF SUGAR PINE.

Sugar pine is comparatively free from diseases of the crown. A very peculiar witches' broom, however, is found on many trees in the shape of a small ball, consisting of exceedingly short, brittle twigs and very small, brittle, bluish needles. This seldom has a diameter of more than from 4 to 8 inches, and is generally of no economic importance. Several hundred of these balls, however, have been found on a sugar pine of pole size, showing that under certain circumstances a seemingly harmless disease may become injurious. The cause of the disease is unknown, but it is evidently of parasitic character.

TIP-DYING OF WHITE AND DOUGLAS FIR.

White and Douglas fir saplings and poles often have dead, yellow, or brown tips hanging from the otherwise thrifty branches. This may be the result of an attack by a fungus which invades the young, bright-green shoots developed in spring, when they are about 1½

inches long. The disease, by killing all the branch tips and the leaders, brings about faulty branching and spike tops, giving the tree a shrubby appearance and sometimes stunting it to such an extent as almost to change its entire aspect. The disease also seriously impairs the natural straight growth of young stuff. Similar symptoms may be caused by late frosts or by insects.

BLACK COBWEB FUNGI.

The fungi *Herpotrichia nigra* and *Neopeckia* are found only at high elevations with abundant snowfall. They are very common on seedlings and saplings of all conifers growing in such situations, particularly on lodgepole pine, incense cedar, and red and white fir, and sometimes cause considerable damage. The black mycelium of both fungi lives on the outside of the needles. It grows under and on the snow, covering the bunches of needles with a brown or black, coarse cobweb, and killing them. The spores are formed in very small, round, black fruiting bodies, which develop on the mycelium.

PINE GALL FUNGUS.

Stems and branches of young yellow, Jeffrey, sugar, and lodgepole pines often show a peculiar roundish swelling, usually from one-half to 4 or more inches in diameter and from 1 to 5 inches long. On the trunks of lodgepole pine, however, the galls may be much larger. The fungi (*Peridermium harknessii*, Pl. I) which causes them belongs to the rusts. The bark of the

swellings comes off in flakes, revealing a bright orange-yellow powdery coating, partly covered by a thin white film. The same orange-yellow powder consisting of spores escapes from small bladder-like pockets with a thin white lining, which are conspicuous between the bark cracks of the swelling. The wood in these galls is excessively developed; the regular channels in the sapwood through which the water is pumped up beyond the galls are disturbed, and the water flow ceases. The living bark is killed and destroyed. As long as the upward flow of water in the wood of the branch and the downward flow of food prepared in the needles are not completely stopped, a very rich but temporary development of foliage beyond the gall may result from the girdling action of the fungus. Such strikingly full and luxuriantly green branches are sometimes very conspicuous on yellow pine, where, however, they may also be the result of girdling by mistletoe. (See Mistletoes, p. 56.) In time the flow of water and prepared food is cut off, and the branch and needles beyond the gall die. This disease constitutes a serious menace to seedlings and smaller saplings of yellow and Jeffrey pine, frequently killing them in groups. When it attacks the leader it seriously interferes with the normal growth of the young tree. Lodgepole pine, especially in the northern California forests, suffers severely, many seedlings being killed, and trees up to pole age completely stunted, and sometimes killed. The very similar galls on Monterey pine are also caused by a *Peridermium* (probably *P. cerebrum*).

DISEASES OF ROOTS, TRUNKS, AND LIMBS.

EFFECT.

Typical diseases of the stem (heartrots) invariably do a great deal of damage by destroying merchantable timber, often, however, without impairing the health and growth of the tree except in weakening it mechanically. Different fungi act in different ways on the wood they inhabit; in other words, every fungus causes a more or less characteristic decay by which, in many cases, we can determine the kind of fungus in the absence of fruiting bodies (sporophores). Entering the tree through a wound or some other opening in the bark, the mycelium of the fungus grows in the dead heartwood. As a rule the living sapwood is untouched. The inability of most of the fungi of this class to invade living tissue explains why they are only found on older trees and not on younger ones, which contain no or very little heartwood. The age at which the trees of a given species may become infected varies and is closely connected with the age at which the species forms heartwood; it varies also with the species of the attacking fungus. In general, diseases of the trunk are rare in sugar pine, more frequent in yellow and Jeffrey pine, common in Douglas fir and red fir, and very common in incense cedar and white fir.

The fungi which cause root diseases, on the other hand, are able to attack living tissue, at least when offered entrance by a wound caused by rodents, plowing, etc. They invade and kill the living bark, the

cambium, and the sapwood. As long as connecting parts of these remain intact, the tree will not die, though it may be greatly weakened. With the progress of the fungus, however, the remaining sound sapwood can no longer supply the crown and foliage with water. The weakened foliage stops respiration and assimilation; bark and cambium are not sufficiently nourished, and the root system is starved. The final result is death of the tree. The fungi of this group are not, as a rule, confined to trees of any particular age.

Root diseases can not well be separated from diseases of the stem, since the fungi which cause them, after living for a while off the roots, may, except in very resinous trees, invade the trunk. Root diseases of forest trees, which, with few exceptions, are at present not very important in District 5, are caused by fungi with porous or gill-bearing fruiting bodies, which grow on the roots and on the collar of the tree. Where they do appear, however, they are extremely injurious. They spread not only by dissemination of spores, but also from infected roots to sound ones of neighboring trees. White mycelium found at the collar of a living or recently killed tree, between the bark and wood or between the bark scales, usually indicates the presence of a fungus of this class. Not always does the fungus enter the heartwood. In the pines resin prevents the mycelium from entering the wood of the trunk. In spruce and fir, however, the trunk is invaded and destroyed. Resin flow on the lower part of the trunk often indicates diseases of this kind.

ROOT FOMES.

This fungus (*Fomes annosus*—pronounced fomeez) is considered in Europe one of the most dangerous forest fungi, and is also destructive in the eastern United States. Although at present apparently somewhat rare in California, it may prove to be more prevalent. It attacks almost all conifers of all ages and some broadleaf trees. The infection starts in the roots and spreads upward, destroying bark, cambium, and sapwood and causing the sudden death of the tree. The heartwood first appears streaky (bluish) and later shows the very characteristic red rot, with small, elongated, perpendicular white pits, often with a black center (see *Trametes pini*). Between the bark scales a very fine mycelium appears. In resinous trees the rot is confined to the butt, but in less resinous ones, such as firs, it reaches far up the trunk. The disease spreads not only by spores, but also from diseased roots to the sound ones of neighboring trees. Whole groups of trees can thus die within a very short time (see, however, *Armillaria mellea*). In this connection it should be remembered that the sudden dying of groups of trees may also be due to attacks by barkbeetles.[1] The perennial fruiting bodies of the fungus are more or less crust shaped, and porous, and usually grow on the roots, but sometimes on the collar of the tree, though generally below the surface of the soil. They are tan colored, with a white underside and margin.

[1] See publications of the Bureau of Entomology.

RING SCALE FUNGUS.

The ring scale fungus (*Trametes pini*—pronounced trameeteez) causes one of the most destructive diseases of living mature and overmature conifers. Though the perennial fruiting bodies reach a great age—50 years or even more—they are seldom very large, and vary in shape according to the host they grow upon. (Pls. IV and V.) As a rule they are irregular, hoof-shaped, the upper side grayish black, rough, dull, often cracked, with concentric furrows parallel to the rather conspicuous narrow, velvety, light brown margin. The underside is light grayish brown. The pores are very large and irregular, varying from relatively small, angular ones near the margin to long, sinuous holes forming a maze with irregular meshes. The substance of the fruiting body is rusty brown in color, and cuts like cork. On the pines the fruiting bodies grow out through branch scars, and, as a rule, only one or a very few of larger size are developed. On white and red fir they are generally smaller. On Douglas, white, and red fir they often form directly on the bark, usually in large numbers. Because of their inconspicuous coloring they are easily overlooked. The mycelium spreads rapidly up and down the tree. A cross section of the heartwood shows that certain annual rings are more affected by the fungus than the others, hence the name "ring scale" (Pl. VI), and also that the action of the fungus is confined almost entirely to the soft springwood of the annual ring, though the color of the hard summerwood

is usually somewhat darker than normal. Split heartwood shows numerous perpendicular white spots or hollow pits, lacking, however, the black centers of those in wood destroyed by root fomes. (Pl. VI.) In species which do not contain much resin the decay may attack the sapwood also.

The fungus gains entrance through knots and wounds, and grows in the tree for some time before the fruiting bodies develop. To destroy these does not destroy the fungus itself, and new fruiting bodies are soon formed in place of old ones. Trees infected with ring scale fungus should not be tolerated in the forest.

CHALKY QUININE FUNGUS.

The chalky quinine fungus (*Fomes laricis*, Pls. VII and VIII), forms, together with *Trametes pini* and *Armillaria mellea*, the only serious menace to sugar pine, on which it is most often found. It may, however, attack Jeffrey, yellow, and lodgepole pine, Douglas fir, and other conifers. The fungus causes a red heartrot, with felts of white mycelium resembling somewhat the decay produced by the sulphur fungus. On sugar pine the fruiting bodies are generally very large, round, and hoof-shaped, with a rough, white chalky surface, which becomes slightly yellow or light brownish with age. The substance of the perennial fruiting body is white, soft and mushy when fresh, chalky and friable when dry, and extremely bitter to the taste. When rubbed, the surface stains the fingers

white like chalk. The pores on the underside may wear off with age. The fruiting bodies often grow on large open wounds, forming large irregular, perpendicular rows. Two or more fruiting bodies may appear on the same tree at different heights. Altogether the fruiting bodies are not common.

SULPHUR FUNGUS.

The sulphur fungus (*Polyporus sulphureus*, Pl. IX) often attacks living and dead mature and overmature oaks, chinquapin, and red fir, but is found also on Douglas and white fir, and yellow and Jeffrey pine. It is very common and exceedingly destructive. The annual fruiting bodies appear in clusters of large, rather flat, yellow shelves. The upper side of the fruiting body is smooth and bright yellow, sometimes light brick color. The smooth underside is brilliant sulphur yellow, with small pores. The cheesy, juicy interior is yellow. During summer and fall the fruiting bodies dry up, and turn either a dirty yellow, or more often a chalky white, and become at the same time brittle. They can easily be distinguished from those of *Fomes laricis*, however, by their flat-shaped growth in clusters, and absence of bitter taste. The fungus causes a red heartrot, with very broad and thick white felts of mycelium (Pl. X), often forming a white star on a cross section in the center of limbs and younger trees. The sulphur fungus is the most destructive enemy of red fir.

INCENSE CEDAR DRY-ROT.

The dry-rot of incense cedar (called in the East "peckiness" or "pin-rot" (Pls. XI and XII), caused by the fungus *Polyporus amarus*, is one of the most characteristic tree diseases. The rot consists of brown, oblongated pockets, from one-half inch to several feet long, filled with a brown, charcoal-like mass, and separated from each other by apparently sound wood (Pl. XII). The fungus evidently enters through wounds or knots, destroys the heartwood, but rarely attacks the sapwood. The annual fruiting bodies (Pl. XI) are at first extremely soft and mushy, and later become cheesy and somewhat tough. Originally knob-shaped, they soon become bracket-shaped, with rounded tops. Fully developed fruiting bodies resemble a bell cut lengthwise in half. When young they are smooth and tan-colored on top, with the underside a bright sulphur yellow, becoming brown with age. They issue from knot holes, and develop in summer and fall, occasionally after the death of the tree. Being fleshy, they are devoured by squirrels and insects, and the place they once occupied can easily be recognized by the shot-hole effect of the larvæ holes in the cup-like depression of the outer bark hollowed out by woodpeckers (p. 23). Seldom is more than one fruiting body found on a living tree at one time. Trees less than 2 feet in diameter are generally free from the disease unless they are badly suppressed. The lower and middle parts are the most affected.

POLYPORUS SCHWEINITZII.

Polyporus schweinitzii (Pl. XIII) is one of the most serious enemies of Douglas fir, and also occurs on certain pines and on white fir. It continues to live and fruit long after killing its host, and rapidly destroys the economic value of the timber. The disease generally appears on the roots and lower parts of mature trees and spreads upward. The decayed wood is reddish brown, with very thin, resinous crusts of mycelium. Later it becomes friable, and is easily crushed between the fingers to a yellow powder. The presence of the disease is often disclosed by resin flow on the bark at the base of the tree. The annual fruiting bodies, which usually appear on old wounds at the base of a tree, a little above the ground, or on the soil coming from dead tree roots, have a characteristic short, thick stalk, are rather large, reddish to dark rusty brown in color, with a yellow margin, cheesy when young, and soft and corky when dry. The porous underside of fresh fruiting bodies is dirty green, and turns deep red brown when bruised. The old dry fruiting bodies from dead tree roots closely resemble old cow dung.

RED-BELT FOMES.

Red-belt fomes (*Fomes pinicola*, Pl. XIV) is the commonest timber-destroying pore fungus in California, attacking all the important conifers, except incense cedar, juniper, redwood, and bigtree. The perennial

fruiting bodies are large, blackish on the upper side, creamy white on the underside, and usually have a broad reddish to chestnut-colored, shiny belt above the light margin. On standing trees they are usually hoof-shaped. The underside is more or less horizontal, smooth, with very small pores, and the margin rounded. They vary considerably in shape, however, according to where they appear. On the underside of logs they may form rounded burls or knobs, while on the upper side they occasionally appear in the form of short-stalked, broad toadstools. The substance of the fruiting bodies, which shows distinct layers, is tough, stringy, later woody, and of a very light yellow brown or isabel color. Drops of a clear liquid often hang from the white underside of the fruiting body. The fungus produces a very characteristic red rot in the heartwood, with broad, white felts of mycelium. It is exceedingly destructive to fallen timber, and may cause damage to living trees as well. On the other hand, it acts as a scavenger on waste logs, which are transformed within a comparatively short time into a punky mass. This punky wood, however, presents a serious fire menace. A single spark will set it to smouldering for days or even weeks until a strong wind fans it into a blaze.

POLYPORUS DRYOPHILUS.

Polyporus dryophilus is very common on living oaks. The annual fruiting bodies are conspicuous, and either grow on the side of the stem or limb, when they are hoof-shaped, or else hang from the underside of the

limb, when their shape is that of a broad bell. The entire fruiting body is light tan color, though the underside is slightly lighter than the upper. The latter is smooth and distinctly velvety to the touch, especially toward the margin. The pores of the underside are rather small. The substance of the fruiting body varies in color from tan to brown. The fungus causes a destructive heart-rot, which is characterized by coarse, dark-brown, and yellowish-white fibers.

FALSE TINDER FUNGUS.

The false tinder fungus (*Fomes igniarius*, Pl. XV) is confined to deciduous trees, and is especially common on willows, cottonwood, and quaking aspens. It causes a white heart-rot which sometimes extends into the sapwood. If only the heartwood is destroyed, the tree may live for many years, until it is finally broken off in a storm or heavy snowfall. When the living sapwood becomes diseased, however, the damage is more serious. While the perennial fruiting bodies do not grow in groups, a number may appear on the same tree, issuing from branch scars. They are hard and usually hoof-shaped. In size they vary a good deal, but are rarely very large. When young the upper side is velvety and brown, and when old, dull brown to almost black, concentrically furrowed and cracked. The margin is velvety and of a lighter rust-brown. The underside is a grayish rust-brown to cinnamon, with small pores. On the smooth, light bark of the host tree the dark fruiting bodies stand out very conspicuously. The

substance shows distinct annual layers, and the age of a fruiting body can with a certain degree of accuracy be determined by cutting it lengthwise and counting these.

WHITE POUCH FUNGUS.

The white pouch fungus (*Polyporus volvatus*), which causes a slow-working, rather superficial gray rot, is not considered parasitic; it does not endanger living trees, but it is very common, and a short description of it will, therefore, be given here. The annual fruiting bodies appear on most conifers, with the exception of juniper, redwood, and bigtree, very soon after the death of the tree, and sometimes on dead parts of a living tree. They are rather small, light yellow-brown when young, white with age, hoof-shaped, and soft corky to hard. The entire surface is very smooth. The underside, with its tiny spores, is hidden by a thick, leathery skin, which forms a pouch. The pink spores escape through a small hole in this skin.

INDIAN PAINT FUNGUS.

The stringy brown rot of white fir, common throughout California, is caused by the Indian paint fungus (*Echinodontium tinctorum*, Pls. XVI, XVII, and XVIII), a very destructive organism, with a large, black, hoof-shaped, perennial fruiting body. The spines or teeth on the underside of the latter are large and hard and point downward. The interior is a vivid rust-red, and was used by Indians for the preparation of war paint. The fruiting bodies grow on the trunk some dis-

tance up, and from four to six or more may appear at different points on the same tree. They never grow out through the bark, but invariably issue from pin knots or branch stubs. The mycelium from which the fruiting bodies spring can only get to the exterior of the tree by way of branch stubs bridging from the heartwood through the sapwood to the outside. In doing so, it decomposes the wood of the stubs, which then, in most cases, show streaks of the same rusty color that characterizes the inside of the fruiting bodies. These "rusty knots" are an infallible sign of decay from the action of the Indian paint fungus in the heartwood. In scaling seemingly sound white fir logs, careful attention should be paid to pin knots and branch stubs. Sound stubs are hard and brittle and break off easily when hit with the U. S. marking hammer or a similar instrument. Unless the log ends show decay, about 3 to 4 linear feet in both directions from the rusty knot should be allowed for cull. The rusty red color appears also in streaks in the stringy reddish-brown rot of the heartwood, which usually leaves but a thin shell of sound sapwood to support the tree. The stringy brown-rot represents one of the last stages of decay. In the first stages the timber appears practically sound to the casual observer; a closer investigation, however, will show that the wood is more or less discolored and spongy. Length sections reveal small light-brown spots. This timber, which has only recently been invaded by the mycelium, causes serious trouble in so far as it will fall to pieces in drying after going through the mill (see "advance rot," p. 28).

The advance rot extends about 2 to 6 linear feet beyond the unmistakably decayed timber; in scaling, it should be treated as cull. Besides white fir, the fungus may also attack Douglas fir, and occasionally red fir. It is often connected with cankers caused by *Razoumofskya occidentalis* (p. 58).

HYDNUM ERINACEUS.

This fungus is sometimes found on oaks. The large, head-shaped, annual fruiting bodies are white, very fleshy and juicy when fresh, but later dry up to small brown or blackish masses. They are often destroyed by insects. Soft, white spines or teeth cover almost the entire fruiting body. In the course of the disease the heartwood of the tree becomes lighter in color, finally appearing almost white, and is rapidly and completely destroyed. The stems of oaks affected with this rot often consist of but a hollow shell of sapwood.

HONEY FUNGUS.

The honey fungus (*Armillaria mellea*, Pls. XIX and XX) is one of the most destructive root fungi of oaks and orchard trees (oranges, apricots). In our forests it does not appear to be very common, but it is likely to spread. It may attack coniferous trees (sugar pine, white fir) of all ages, often spreading through diseased roots to roots of sound neighboring trees, which it kills in a short time. The butt of affected coniferous trees often shows a heavy outflow of resin. Con-

spicuous tough felts of white mycelium under the bark distinguish this fungus from the root fomes (*Fomes annosus*) with its very thin mycelium. Another characteristic of the honey fungus consists in the black-brown round or flattened strands, "shoe strings," which are found under the bark or in the soil near the affected tree. The parasite is, in fact, sometimes called shoestring fungus. The annual fruiting bodies are honey-colored mushrooms with gills (Pl. XIX), the stalks bearing a thin yellowish ring. They grow in great numbers on stumps, bark, or on the ground near the base of living or dead trees.

SCALY LENTINUS.

Although it is not certain that the scaly lentinus (*Lentinus lepideus*) actually attacks living trees, there are indications that it does so. It is certainly very destructive to dead timber. The big white annual fruiting bodies are often found in large clusters on the butts of Jeffrey, yellow, and lodgepole pine. Occasionally, however, they grow on the dead roots of living trees and also high up on the trunk. The underside of the fruiting body has no pores, but is provided with wide white gills standing on edge and radiating from a central stalk which is tough and fleshy. The fruiting bodies resemble irregularly shaped white mushrooms, the upper side of which is at first covered with broad yellowish, and later, grayish-brown scales radiating from the center to the margin.

MISTLETOE.

Our forests have, perhaps, no more widely distributed parasitic enemies than the mistletoes. Two kinds of mistletoes grow on forest trees; one belonging to the genus *Phoradendron*, an example of which is the ordinary Christmas mistletoe, the other belonging to the genus *Razoumofskya* (*Arceuthobium*), and confined to coniferous trees. *Phoradendron* is the larger of the two and may have leaves, as on oak, or be leafless, as on incense cedar. Its berries are round, white or pink, and contain a seed imbedded in a thick, extremely sticky glue. The seeds are carried by birds from one tree to another, adhere to the bark, and germinate. The *Phoradendrons* are light-seeking, and therefore grow high up in the tree (Pl. XXI). *Razoumofskya* (Pl. XXII) is smaller. The thin and brittle stems stand out from the branch they grow on like a small yellowish brush. The oval berries hang on erect stems, and are light green in color. In ripening they develop a considerable inside pressure, which increases until the slightest disturbance is enough to make them explode and eject the seed with some force. These are scattered about at random, and many perish for lack of food; others stick to the bark of young branches and twigs and germinate. The Razoumofskya species are more tolerant of shade than the Phoradendrons.

Mistletoe seeds of both groups can germinate under normal conditions almost anywhere, but they can penetrate only the young, thin bark of those hosts to which they are adapted. For example, Razoumofskya seeds

(embryos) thrown from a Jeffrey pine onto a twig of an oak standing beneath it can germinate, but can not penetrate the bark and enter the living tissue. The same seed landing on a young Jeffrey pine twig, however, develops a small rootlet, which perforates the bark. From this rootlet are developed other roots (cortical roots) running up and down in the bark of the twig, and from these again so-called sinkers are started—that is, roots growing straight down to the wood. In the meantime, the mistletoe plant develops on the outside of the twig at the cost of the host tree.

The damage the mistletoes of both groups cause to their host consists less in depreciation of timber than in the attack on the vital organs of the host. They belong to the higher plants which are characterized by roots, stems, green foliage, and flowers. Parasitic life has robbed the mistletoes of their independence. They are unable to take raw food from the soil; their root system is much reduced and has adapted itself to the function of tapping the tissues of their hosts. The foliage of the Razoumofskyas is reduced to small scales and they contain very little green pigment (se p. 9) with which to assimilate carbon dioxide from the air. They depend, therefore, upon their host not only for water, but also for the greater part of elaborated food. The Phoradendrons, on the other hand, generally possess green leaves, or, at least, green stems. They elaborate their own food and normally draw only water and raw food from the host.

The effect of the mistletoe on its host is chiefly that of a parasite tapping the saps and girdling the branch

it grows on. The irritation of the cambium by the roots of the mistletoe results in a considerable swelling of the branch at the point of attack. The wood of such swellings is very characteristically marked by longitudinal rows of small holes made by the sinkers. The holes caused by the sinkers of *Phoradendron* are particularly conspicuous.

Mistletoes do not often kill outright. Girdling by *Razoumofskya* can even stimulate for quite a time the growth of the branches and leaves above the point of attack. This luxuriant growth, however, is of little benefit to the tree. The food prepared in the excess foliage above the mistletoe serves to nourish the mistletoe plant, and barely sufficient food is allowed to go below to the roots to keep them from starving. In many cases the attack ends in the death of the branch or limb, and when many limbs are affected in the death of the tree. *Razoumofskya* very often causes a formation of witches' brooms (p. 21). Large formations of this kind, often resembling richly branched, low-hanging limbs, with profuse foliage, are very conspicuous on sugar pine, yellow pine (Pl. XXIII), and Jeffrey pine, and common on lodgepole pine (Pl. XXIV) and Douglas fir. *Phoradendron* sometimes lives for a great many years and then causes swellings and deformations, for instance, on trunks of incense cedar, where the parasite has been known to live for more than 220 years. As the rather brittle mistletoe shrubs break off easily, rarely lasting more than 10 years, new shrubs are formed from buds breaking through the bark of the host, as long as the bark is not too

thick. In cases where incense cedar mistletoe, for instance, has grown to a high age with its host tree, the bark of the latter becomes so thick that it can not be pierced by the young mistletoe sprouts. The mistletoe then lives without green parts, consisting only of cortical roots and sinkers, and depending altogether for all food on its host. In this state it acts very much like a fungus, which also is unable to elaborate its own food and has to rely upon other plants (see p. 24).

Phoradendron rarely attacks young trees. *Razoumofskya*, on the other hand, very often does considerable damage to young yellow, Jeffrey, and lodgepole pine. If the stem or leader is infected, the young tree is killed in the course of time, or at least prevented from developing a straight, clean bole. Different species of *Phoradendron* and *Razoumofskya* are confined to certain hosts. *Phoradendron juniperinum libocedri*, for example, grows on incense cedar; *Phoradendron juniperinum* on junipers; *Phorandendron bolleanum* on white fir and juniper; *Phoradendron flavescens* on oak and other broadleaf trees; *Razoumofskya campylopoda* on sugar, yellow, and Jeffrey pine; *Razoumofskya americana* on lodgepole pine; *Razoumofskya douglasii* on Douglas fir; and *Razoumofskya occidentalis* on white fir.

Our white fir is the host of both a *Phoradendron* and a *Razoumofskya*. The light-seeking *Phoradendron bolleanum* lives exclusively in the very top of the older trees, chiefly in the leader, and there develops the conspicuous tufts of green foliage, which even at a great distance reveal the presence of the mistletoe. It finally kills the leader, which is replaced by a secondary leader,

and this, too, is often killed. This "top" mistletoe is responsible for by far the greater number of spike tops in white fir, though these are caused also by lightning and the Tussock moth. *Razoumofskya occidentalis*, which inhabits white fir of all ages, grows lower down on twigs and branches and is also often found on limbs and the trunk. As it can not penetrate old bark, the infection must in the latter case have taken place when the tree was young. This shows that the tree can live for a long time after infection. The effect on the trunk is the development of huge barrel-shaped swellings, which later break and present a large open wound or canker. Besides rendering this part of the tree wholly unmerchantable, the swelling, made up of unhealthy and abnormal tissue, weakens the tree very considerably, while the open wound offers an easy entrance to germinating spores of *Echinodontium tinctorum*, the cause of the reddish-brown, stringy heartrot. White fir snags, broken off in a storm either just below or above the canker or in the swelling itself, are extremely common. Almost all trees with canker are completely worthless from decay. All white fir with this mistletoe should be cut and utilized as soon as possible.

CONTROL OF DISEASE.

It is impossible to grow sound, thrifty young trees for future stands if conditions in the forest are such that there is constant danger from insects and disease. Every diseased or abnormal tree (leaning, forked, etc.) in the forest, as well as every snag, in other words, every individual that can not finally produce the great-

est amount of high-grade merchantable timber, acts as a parasite on the whole community; it takes space, light, and food from the sound trees and places them in constant danger from infection, attack by insects, and fire. The forest is a community of living trees, which breathe, assimilate food, grow, adapt themselves to surrounding conditions, and struggle for life, and which are subject to diseases and injuries from which they may succumb if not helped in time, exactly like any other plant and every animal. The forester in charge of these living beings must endeavor to eliminate any danger to their health, to prevent their injury, and to establish sound conditions for their growth. These are the objects of forest hygiene, upon the application of which the welfare of the community depends.

The first step in any hygienic work is close observation. Unless the field man keeps a sharp lookout for signs of disease or abnormality in individual trees, he will in all likelihood fail to see an unhealthy condition in the stand and so lose the opportunity to remedy it. Under "Symptoms of disease," page 18, a number of hints are given on how to recognize any trouble.

There are a number of injurious factors which we can not control, such as lightning, drought, and floods. Fires which can be controlled have more to do with decay of forest trees than is commonly supposed, since fire scars very often offer an easy entrance to wood-destroying fungi and to wood borers.

It is manifest that expensive measures, such as treatment of wounds, pruning, spraying, and the construction of isolation ditches, can not be applied in our enor-

mous forests as in the smaller and more valuable European forests, or in orchards and parks. Methods must be adapted to existing conditions.

Very rarely will it be possible to save a tree or a stand which has once been attacked by one of its more dangerous enemies. A tree infected by a heart-rot fungus or by a large colony of Dendroctonus beetles is lost. We can not save it. We can not even always save all of its timber; part of it may already be destroyed or at least injured. This leads to our first rule: Save the merchantable timber of a tree as long as the amount to be saved justifies it. This simply means closer utilization of our timber supply.

The second rule in dealing with disease is to prevent the infection and infestation of sound stuff by getting rid of all diseased and insect-infested living or dying trees. This means sanitation of our forests. Insects, fungi, and mistletoe, however, are so widely and uniformly scattered throughout our forests, and have such a firm hold, that without improved methods of forest management it will take long and persistent work to control them.

There is a fundamental difference between attacks by insects and by parasitic plants (fungi and mistletoes). While insects are always present in the forest, it is only at considerable intervals that they do widespread harm in any given locality. A destructive species, however, may multiply enormously and kill a large number of trees in a short time. Under natural conditions it may continue to increase in number for years until it is again reduced by some natural agency to a

scattered and harmless condition. Parasitic fungi and mistletoes, on the other hand, develop rather slowly, and spread their activity over long periods. Sudden outbreaks of disease, regular epidemics, are rare. The only sudden danger might come from leaf, twig, bark, and root diseases.

Prevention is the basis of control of parasitic fungi and mistletoe. The greatest difficulty lies in the fact that the spores of injurious fungi are found everywhere, being carried long distances by air currents. It follows that fruiting bodies of parasitic tree fungi should be destroyed by fire, if possible, wherever found. A young tree whose stem is affected with mistletoe can never produce a straight, sound trunk. It is therefore better to destroy it, in order to make room for sound reproduction. A mistletoe-infested branch should be cut off some distance from where the mistletoe appears, since its roots may spread rather far toward the trunk in the living bark. Trees with infected stems or trunks can not be saved.

The practice of cutting mistletoe-infected trees outside of timber-sale areas would, of course, be practicable only along roads and trails. More systematic and valuable work can be done by every ranger around his regular station. Just as the neatness and cleanliness of an office would always speak for the quality of the ranger who is in charge of it, so the clean and healthy condition of the forest about the ranger station should testify to the ranger's credit. Ranger sales and free use are means by which the ranger can very materially help in establishing healthy conditions on the forest

at large. Wherever possible all undesirable timber should be used first for these purposes. A tree affected with needle disease, mistletoe, or even bark beetles will usually answer just as well as a perfectly sound one. Incense cedar with dry-rot not too far advanced makes as good posts as sound cedar. A tree once affected by any serious parasite, if left long in the forest, deteriorates very rapidly, and unless the merchantable timber it contains is utilized in time it will go to total waste.

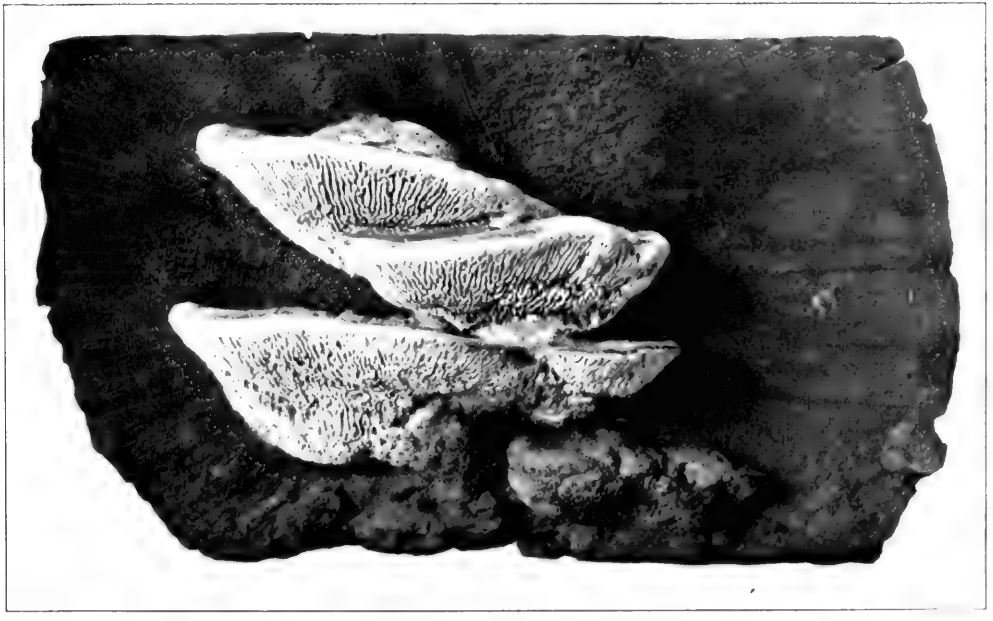
The surroundings of nurseries and planting areas should also present as healthy conditions as possible. We can not expect to raise sound, thrifty reproduction in an insanitary environment.

The difficulties in the way of bettering hygienic conditions and establishing sanitation in our forests on a large scale are, of course, very great. Although it is comparatively simple, for instance, to trace damage to smelter fumes or smoke, it is generally a hard task to stop the trouble. Systematic elimination of the common fungi or mistletoes will take many years. The method which gives the best results is illustrated by a stipulation inserted in the Forest Service timber-sale contracts. This requires the purchaser to cut all trees marked upon the cutting area, whether merchantable or apparently unmerchantable. Trees must be opened up sufficiently to satisfy the forest officer in charge of their condition, and any logs in such trees which, in his judgment, are merchantable must be removed from the woods, scaled, and paid for. This enables the Forest Service to get rid of all undesirable stuff and to

leave only sound seed trees and sound reproduction in healthy surroundings. It also makes possible utilization of merchantable timber left in undesirable trees, which would otherwise go to waste.

One other point should be borne in mind by every forest officer who has to do with marking timber. Seed trees left for reproduction should be sound and not too old. Neither in animal nor in plant life can healthy, thrifty offspring be expected from diseased, weak, or aged parents. The future of the forest depends very largely upon the right choice of seed trees.

FUNGUS GALL ON YELLOW PINE CAUSED BY PERIDERMIUM HARKNESSII.
(Photograph by Dr. Herman von Schrenk.)



DAEDALEA QUERCINA ON OAK RAILROAD TIE. PORES ON THE UNDERSIDE.

(Photograph by Dr. Herman von Schrenk.)

GILL-BEARING FUNGUS (PLEUROTUS).

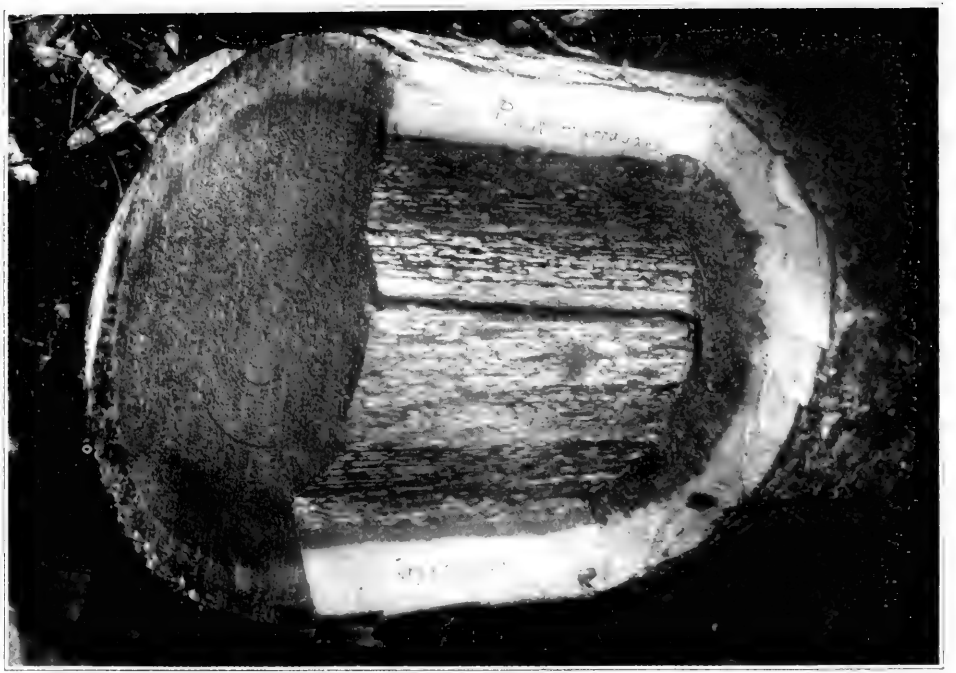
(Photograph by Dr. G. G. Hedgcock.)

TRAMETES PINI FRUITING BODIES ON SHORTLEAF PINE. (COMPARE WITH PLATE V.)

(Photograph by Dr. G. G. Hedgcock.)

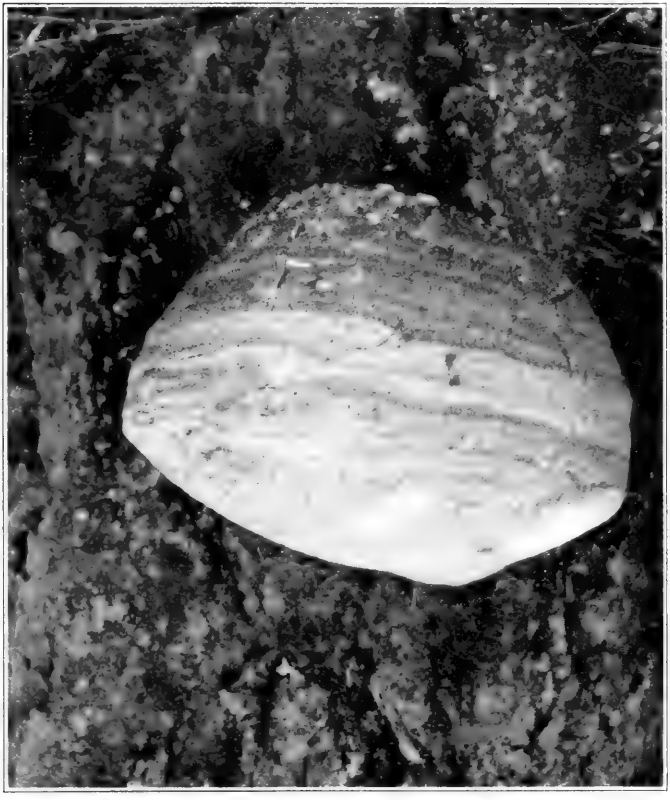
TRAMETES PINI FRUITING BODIES ON LODGEPOLE PINE. (NOTICE, IN COMPARISON WITH PLATE IV, VARIATION IN FORM WITH HOST TREE.)

(Photograph by Dr. G. G. Hedgcock.)



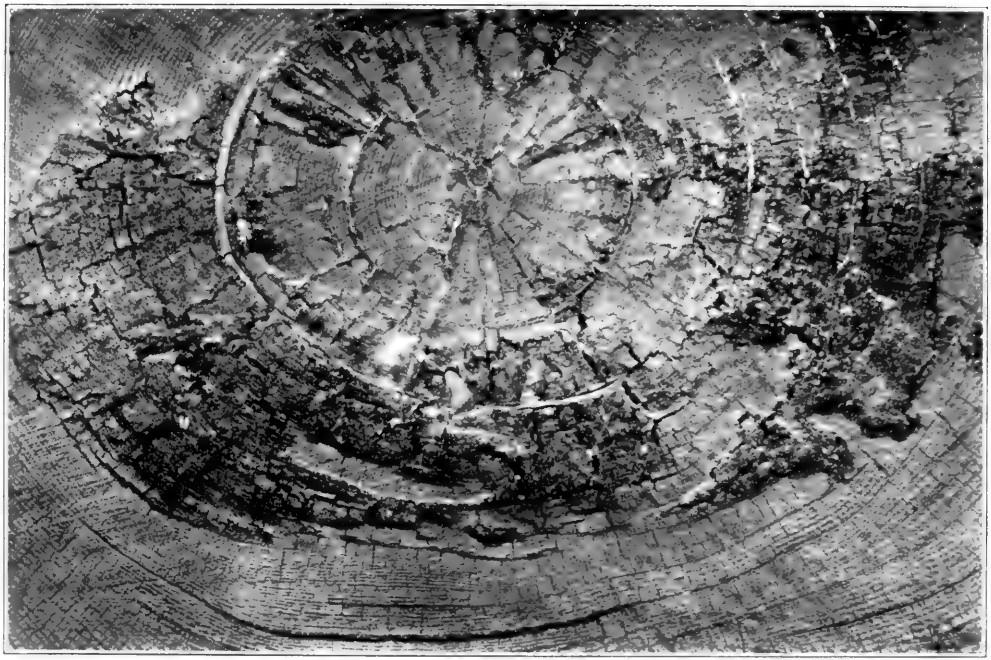
RING SCALE IN LODGEPOLE PINE CAUSED BY TRAMETES PINI, SHOWING ROT WITH THE CHARACTERISTIC WHITE PITS.

(Photograph by Dr. G. G. Hedgcock.)



CHALKY QUININE FUNGUS (FOMES LARICIS) FRUITING BODY ON DOUGLAS FIR.

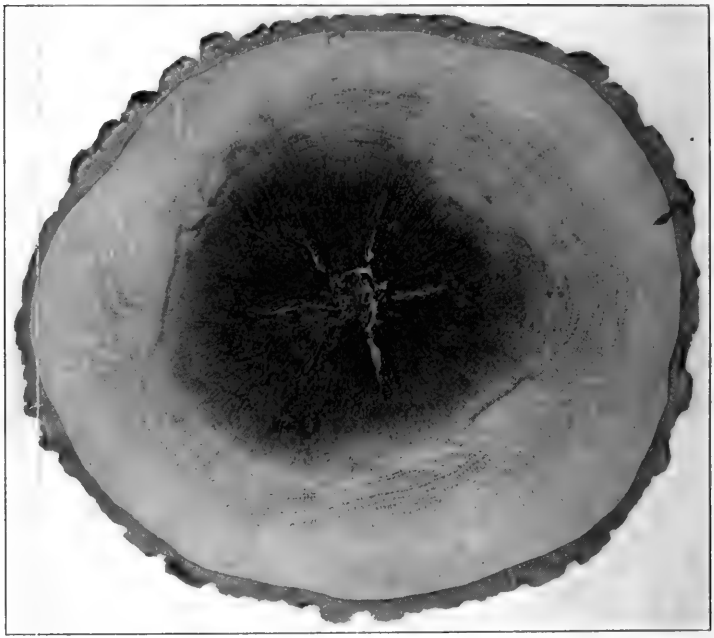
(Photograph by Dr. G. G. Hedgcock.)



CHALKY QUININE FUNGUS (FOMES LARICIS) IN LODGEPOLE PINE. TYPICAL ROT OF THE HEARTWOOD WITH FELTS OF WHITE MYCELIUM IN THE CRACKS.

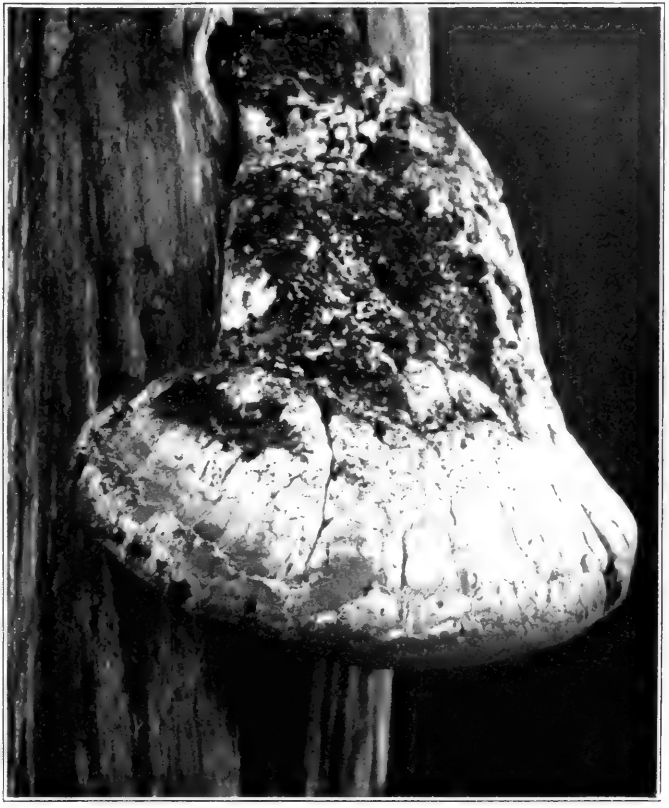
(Photograph by Dr. G. G. Hedgcock.)

CLUSTER OF FRUITING BODIES, SULPHUR FUNGUS (POLYPORUS SULPHUREUS).
(Photograph by Dr. Herman von Schrenk.)



SULPHUR FUNGUS ROT IN THE HEARTWOOD OF OAK.

(Photograph by Dr. Herman von Schrenk.)



FULLY DEVELOPED FRUITING BODY OF INCENSE CEDAR DRY-ROT FUNGUS.

INCENSE CEDAR WOOD WITH DRY ROT. WHITE MYCELIUM OF FUNGUS VISIBLE IN THE ROT POCKETS.

FRESH FRUITING BODY OF POLYPORUS SCHWEINITZII. THE LIGHT MARGIN LATER BECOMES A DARKER BROWN.

(Photograph by Dr. G. G. Hedgcock.)

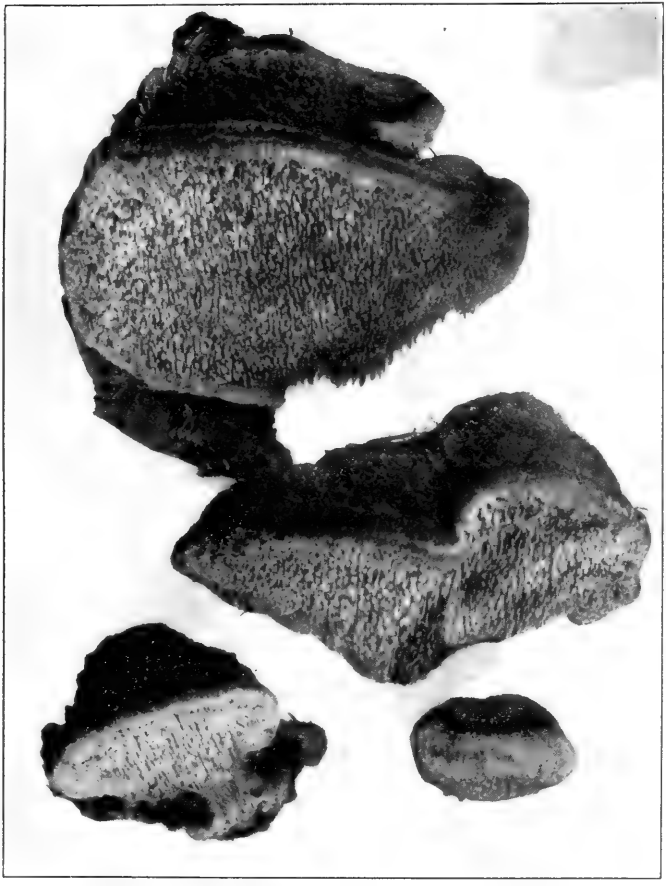
FRUITING BODIES OF RED BELT FOMES ON WESTERN HEMLOCK.

(Photograph by Dr. Herman von Schrenk.)

FALSE TINDER FUNGUS FRUITING BODIES ON ASPEN.

(Photograph by Dr. G. G. Hedgcock.)

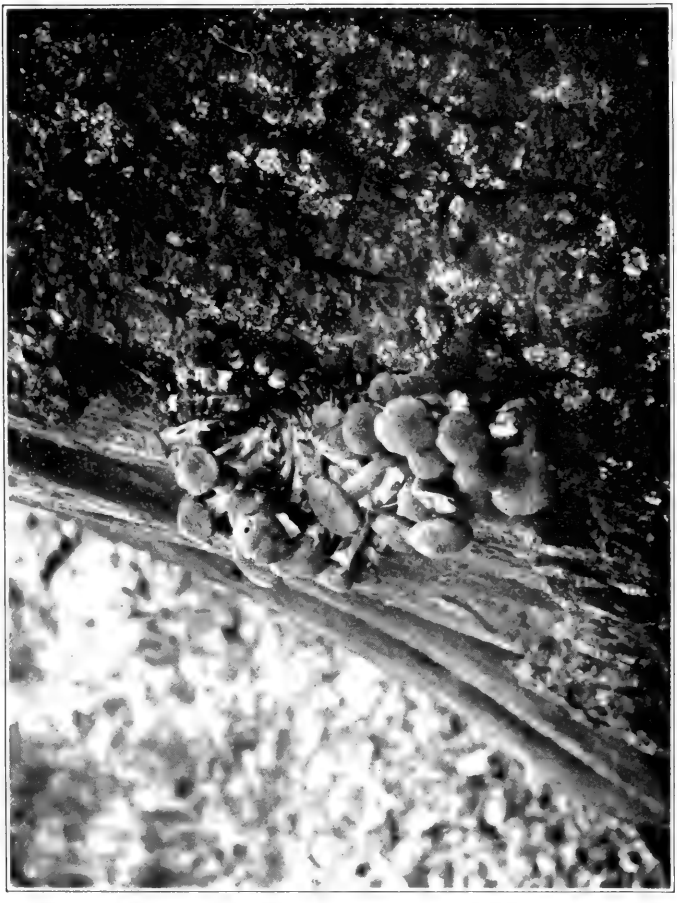
INDIAN PAINT UNGUS FRUITING BODY (SIDE VIEW) ON NOBLE FIR.
(Photograph by Dr. Herman von Schrenk.)



INDIAN PAINT FUNGUS FRUITING BODIES, SHOWING SPINY UNDERSIDES.

(Photograph by Dr. G. G. Hedgcock.)

INDIAN PAINT FUNGUS IN WHITE FIR.
(Photograph by Dr. G. G. Hedgcock.)



HONEY FUNGUS FRUITING BODIES ON OAK.

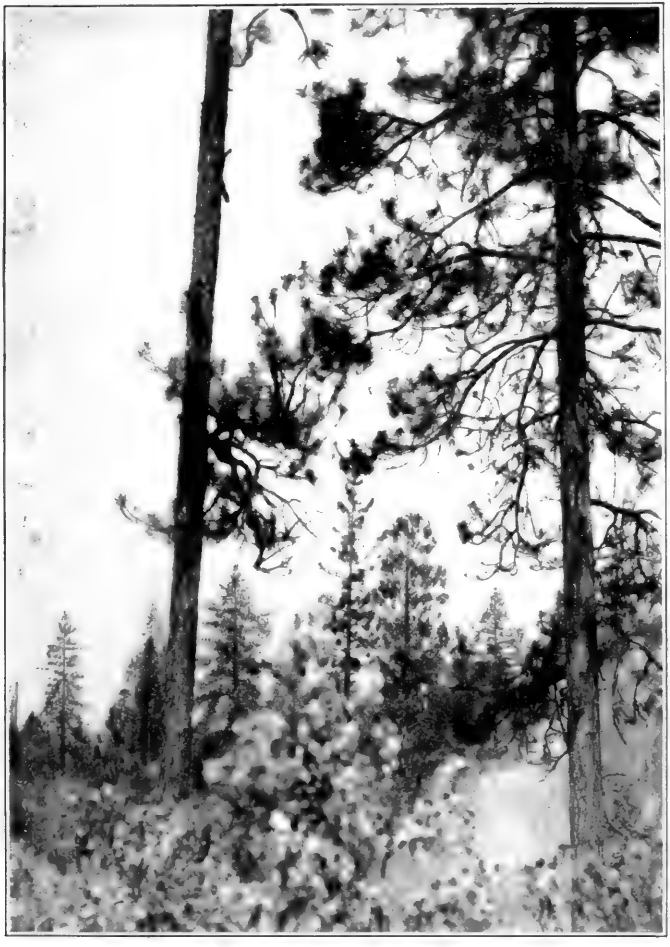
HONEY FUNGUS IN OAK, SHOWING BLACK STRANDS (SHOE STRINGS) UNDER THE BARK.

MISTLETOE (PHORADENDRON JUNIPERINUM LIBOCEDRI) ON INCENSE CEDAR. NOTE THE BUSHES HANGING DOWNWARD.

(Photograph by Dr. G. G. Hedgcock.)

MISTLETOE (RAZOUMOFSKYA AMERICANA), WITH RIPE BERRIES, ON LODGEPOLE PINE.

(Photograph by Dr. G. G. Hedgcock.)



WITCHES' BROOMS CAUSED BY MISTLETOE (RAZOUMOFSKYA CAMPYLOPODA) ON YELLOW PINE.

WITCHES' BROOMS ON LODGEPOLE PINE CAUSED BY MISTLETOE (RAZOUMOFSKYA AMERICANA).

(Photograph by Dr. G. G. Hedgcock.)

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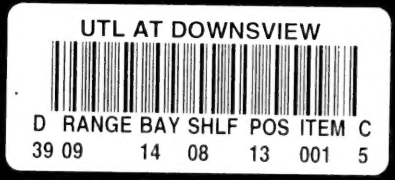
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